Technology Opportunity

Power Systems Dynamics and Control

NASA Lewis has developed the first phase of software-complemented capabilities for dynamics and control analysis of Free-Piston Stirling Engine/ Linear Alternator-based (FPSE/LA) and solar dynamic-based (SD-based) power systems. The software can be used to design and to predict the performance of space- and ground-based power systems.

Potential Commercial Uses

- Guidance in designing space-based or stand-alone, ground-based power systems
- Development and guidance of test programs for an integrated system
- Identification and comparative evaluation of potential system configurations

Benefits

- Provides insight into system performance
- Expedites study of alternative power generation sources and associated controls via modular software
- Yields system interactions and performance prediction by computationally cost-effective parametric variations
- Predicts performance of not-easily-tested operating modes

The Technology

<u>Solar Dynamic-Based Power System</u>

The SD-based software was developed under a NASA-funded university grant. This time-domain software simulates and evaluates the performance of a Brayton-cycle power system. It provides detailed representations of the Lundell alternator and the constituent elements of the system's power management and control (PMAC). Some key parts of the PMAC are illustrated in figure 1: a voltage regulator, a three-phase bridge rectifier and accompanying filter, a parasitic load radiator and its controller (not shown), and a starter inverter (not shown). Some initial simulations of the voltage regulator predicted instability at a regulator sample time of 50 msec. Reducing the sample time by a factor of 10, consistent with a key time-constant of the alternator, yielded nearly stable, but not well-damped, conditions of the regulator. By varying key parameters, one can use the software to design a stable system.

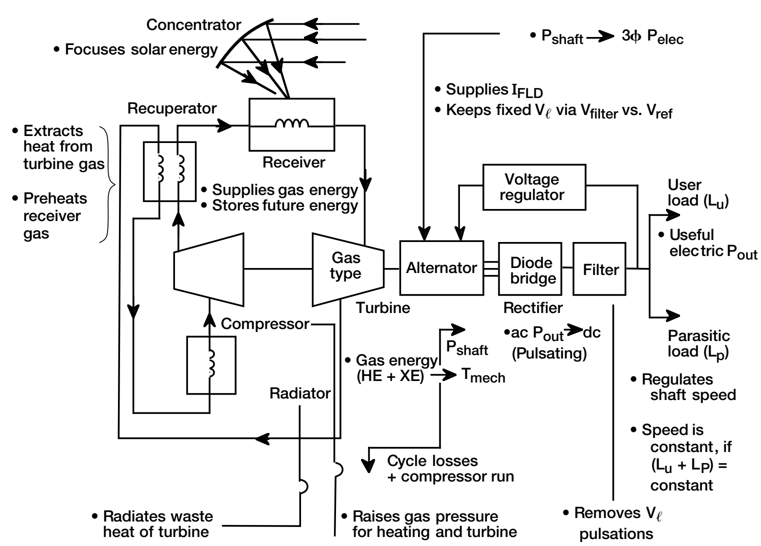

Figure 1.—Schematic of Brayton-Cycle Electric Power Generation System (HE = helium, XE = xenon, P = power, T = torque, V_ℓ = load voltage, I_{FLD} = field current, and 3ϕ = three phase).

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FPSE/LA-Based Power System

The FPSE-based software includes mathematical formulations to evaluate the effect on performance that is due to component and subsystem interactions within the system. Figure 2 shows the dynamic model of the FPSE/LA connected to an external load. Figure 3 depicts the migration of system roots caused by a variation in load resistance RL. The inhouse-developed capability uses the computational platform of MATLAB. The analysis includes the engine and load dynamics. The impact of variations in system parameters is expeditiously evaluated in the frequency domain.

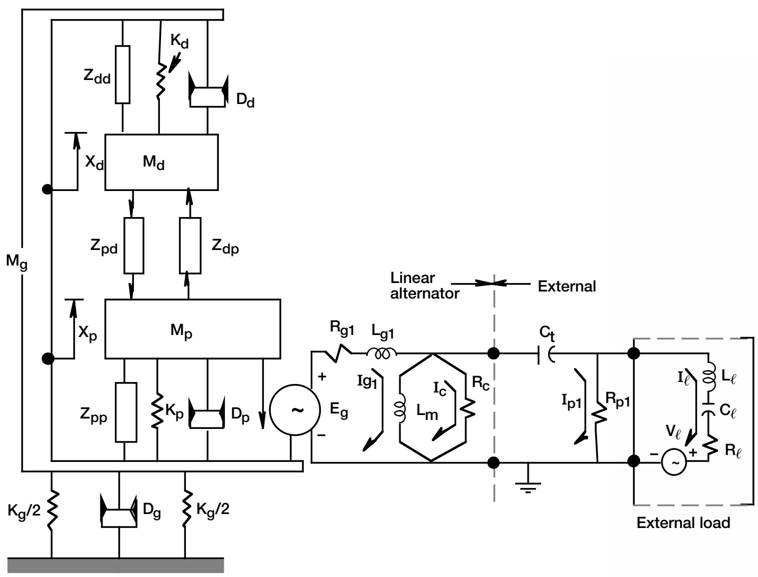

Figure 2.—Dynamic model of Stirling engine/linear alternator connected to external load (C = capacitance; c = core loss, D = damping; d = displacer; dd = between displacer and ground; dp = between displacer and piston; E_g = generated voltage; g = ground; g_1 = generator; I = current; K = spring constant; L = inductance; ℓ = load; M = mass; m = magnetizing; p = piston; p_1 = parasitic; pd = between piston and displacer; pp = between piston and ground; R = resistance; t = tuning; V = voltage; X = displacement; Z = working space).

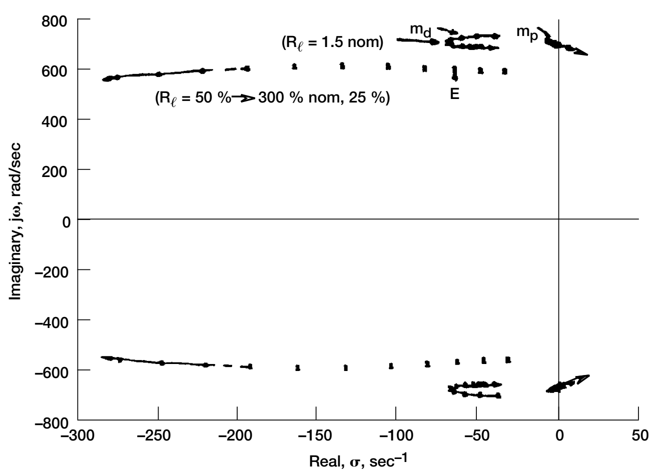

Figure 3.—Plot of system eigenvalues with R_ℓ variation: static resistance-inductance-capacitance load connected ($M_{d,p}$ = mechanical system root; E = electric system root).

Options for Commercialization

Solar-Dynamic-Based Power System

The SD-based software needs to be upgraded to include a frequency-domain formulation and other power-generation sources such as permanent magnet motors, the FPSE, and their controls. With the addition of multiple power sources and their control strategies, further investigation of the issues of voltage regulation, load sharing, dynamic and transient stability, and the effects of harmonic generation will be required. NASA Lewis seeks industry partnership/collaboration to effect such an upgrade for commercial applications.

FPSE/LA-Based Power System

To complement a realistically practical system that requires increased power output, the FPSE-based system software must include multiple engines and their controllers. If the software is extended to time-domain analysis, nonlinearities within the controllers can be more easily accounted for. Results obtained this way may more closely predict the performance of multiple systems that are currently under development through NASA Small Busi-ness Innovation Research (SBIR) funding.

NASA Lewis welcomes industry partnership/collaboration in upgrading this software to embody the aforementioned improvements for commercial applications.

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Key Words

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